

5 This application claims priority to an application entitled “Wavelength path monitoring/correcting apparatus in transparent optical cross-connect and method thereof,” filed in the Korean Intellectual Property Office on February 5, 2003 and assigned Serial No. 2003-7205, the contents of which are hereby incorporated by reference.

1. Field of the Invention

The present invention relates to a transparent optical cross-connect (OXC) in a wavelength-division-multiplexing (WDM) optical-communication network, and more particularly to an apparatus for monitoring and correcting the paths of wavelength channels.

In general, a transmission rate in an optical-communication network can reach a speed of several Gb/s to several Tb/s according to the type of network. In order to meet a high-speed transmission requirement, a large-capacity OXC together with a high speed of DWDM (Dense Wavelength-Division-Multiplexing) optical-transmission system are employed.

Up to now, opaque OXCs using optical-electric-optical conversions have been used predominantly, but henceforth it is expected that transparent OXCs without the optical-electric-optical conversions will be used more frequently within two to three years. In an OXC network, wavelength channels inputted to a transparent OXC are outputted
 5 through optical switches according to predetermined routing/switching information of wavelength channels. Thus, it is necessary to monitor whether the input-wavelength channels are switched correctly at the respective, pertinent output ends according to the routing information of the wavelength channels, which is also known as OXC path monitoring.

10 FIG. 1 is a block diagram illustrating a wavelength-path-monitoring apparatus according to the prior art.

In operation, optical signals of a first input port ($\lambda_1 \sim \lambda_n$) to an N^{th} input port ($\lambda_1 \sim \lambda_n$) are inputted to the respective pertinent FPFs (Fabry Perot Filters) in the optical-amplifying section 10. The FPF is a device used for maintaining laser wavelengths
 15 uniformly. A reference number 10A represents an input port as an example for describing detailed construction and operation of the optical-amplifying section 10. As shown in 10A, optical signals, which are inputted to an EDFA (Erbium-Doped Fiber Amplifier) through an optical coupler *a* of an input point (IN), are transmitted to a FPF through an optical coupler *b* of an output point (OUT), then fed back to the optical coupler *a* of the input point (IN).
 20 The FPF detects the wavelength of an ASE (Amplified Spontaneous Emission) portion outputted from the EDFA according to each input port. That is, the FPF of the first input port detects the wavelength of the ASE portion periodically by utilizing a first frequency f_1 ,

and the FPF of the N^{th} input port detects the wavelength of the ASE portion periodically by utilizing an N^{th} frequency f_N .

The ASE signals and optical-input signals detected by the above method are demultiplexed into individual wavelengths through a plurality of wavelength-division multiplexers (WDMs) 12. WDMs are one type of Arrayed Waveguide Grating (hereinafter, referred to as "AWG"). Then, each optical signal of λ_i is demultiplexed together with a pertinent ASE wavelength of " $\lambda_i + \text{FSR}$ (Free Spectral Range)".

Each ASE wavelength signal is detected by fiber Bragg gratings (FBG) 24 at the output side of the OXC, and then each frequency is detected by a frequency-detection module 20. For example, when an ASE wavelength of " $\lambda_n + \text{FSR}$ " modulated in a second frequency f_2 is detected at a first output port, it indicates that an optical signal λ_n of the second input port has switched onto the first output port.

After each path of the input-wavelength signals are calculated by the ASE wavelength information and the frequency information is detected through the process described above, a comparator 22 compares each of the calculated paths with predetermined routing/switching information so as to check whether or not the input wavelength signals have been switched correctly. If errors are found, a routing-control module 18 controls optical switches 14 to correct the path of the pertinent optical signals.

In order to monitor the paths of wavelength signals as described above, there must be the same number of ASE wavelength channels as there are input WDM channels. However, because the WDM optical transmission system according to the prior art transmits 32 or 64 channels of optical signals utilizing all the wavelength bands of EDFA, it is

impossible to procure any ASE wavelength channels when monitoring the paths of wavelength channels. In addition, $n \times N$ fiber Bragg gratings (n is the number of wavelengths and N is the number of inputs or outputs) are needed which in turn requires $n \times N$ optical receivers for monitoring the paths in the frequency-detection module. This
5 adds a high cost to the manufacturing of the wavelength-path-monitoring apparatus. Another high-cost wavelength-tunable filter must be also used for the purpose of detecting the ASE wavelength.

Accordingly, there is a need for an improved system for monitoring and correcting the wavelength paths of an optical cross-connect device in a simpler and more inexpensive
10 implementation.

SUMMARY OF THE INVENTION

One aspect of the present invention is to provide a wavelength-path-
15 monitoring/correcting apparatus that may be realized in a reliable and inexpensive implementation, by reducing the number of optical receivers and fiber Bragg gratings necessary to monitor the optical-signal paths and a method thereof.

Another aspect of the present invention is to provide a wavelength-path-monitoring/correcting apparatus capable of achieving a low manufacturing cost and a
20 simplification of construction, by detecting switching-information of wavelength channels through a time-slot detection and by using general laser diodes and fiber-delay lines which do not incorporate the high cost FPFs.

In one embodiment, a wavelength-path-monitoring/correcting apparatus in a transparent OXC (optical cross-connect) of a wavelength-division-multiplexing optical-communication network is provided and includes: a path-information-generating section for generating the path-monitoring information so as to check each input port and each
5 switching path of optical signals; a plurality of optical couplers for coupling each output signal of the wavelength-division demultiplexers with pertinent path-monitoring information generated from the path-information-generating section; a plurality of optical switches for switching each optical signal inputted from the optical couplers; a plurality of wavelength-division multiplexers for multiplexing optical signals inputted through the
10 optical switches; a path-information-detecting section for detecting the path-monitoring information from optical signals outputted from the wavelength-division multiplexers; and, a path-control section for comparing the path-monitoring information detected through the path-information-detecting section with predetermined optical-switching information and for correcting erroneously switched paths.

15 In another embodiment, a method for monitoring/correcting the paths of optical signals in a transparent OXC (optical cross-connect) of a wavelength-division-multiplexing optical-communication network is provided. The method includes the steps of: generating an i^{th} frequency for each time frame, the i^{th} frequency having the length of a time slot, optically-modulating the i^{th} frequency to a wavelength channel for path monitoring, and
20 coupling the modulated signal - after delay for predetermined time - with an optical signal inputted to the OXC; detecting a path-monitoring wavelength from the optical-switched signal; detecting the i^{th} frequency and time-slot-position information from the detected

signal of the path-monitoring wavelength; and, calculating the path of an optical signal from the detected i^{th} frequency and time-slot-position information, comparing the calculated path with predetermined path-switching information, and correcting the path of the optical signal according to the comparison result.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram illustrating an optical-signal-path-monitoring apparatus for an OXC according to the prior art;

10 FIG. 2 is a block diagram illustrating an optical-signal-path monitoring and correcting apparatus for an OXC according to a first embodiment of the present invention;

FIG. 3 is a detailed view of an optical-delay module shown in FIG. 2;

FIG. 4 is a detailed view of the frequency/time-slot-detection unit shown in FIG. 2;

15 FIG. 5 is a view illustrating the time frame used in an optical-signal-path-monitoring apparatus for an OXC;

FIG. 6 is a view illustrating the output examples of an optical-delay-module shown in FIG. 2;

FIG. 7 is a view illustrating an example of a time frame inputted into the frequency/time-slot-detection unit according to the present invention;

20 FIG. 8 is a block diagram illustrating an optical-signal-path-monitoring and correcting apparatus for an OXC according to a second embodiment of the present invention;

FIG. 9 is a view illustrating a detailed construction of the input-data-pattern/time-slot-detection unit shown in FIG. 8;

FIG. 10 is a block diagram illustrating an optical-signal-path monitoring and correcting apparatus for an OXC according to a third embodiment of the present invention;
5 and,

FIG. 11 is a view illustrating a detailed construction of the CDM-code/time-slot-detection unit shown in FIG. 10.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

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Hereinafter, a wavelength-path-monitoring/correcting apparatus in a transparent optical cross-connect and a method thereof according to preferred embodiments of the present invention will be described with reference to the accompanying drawings. It is to be noted that the same elements are indicated with the same reference numerals throughout
15 the drawings. For the purposes of clarity and simplicity, a detailed description of known functions and configurations incorporated herein will be omitted as it may make the subject matter of the present invention unclear.

FIG. 2 is a block diagram illustrating an optical-signal-path monitoring and correcting apparatus used in an OXC device according to a first embodiment of the present
20 invention. As shown, a path-information-generating section 10 includes a plurality of frequency generators 100 for generating frequencies different from one another, a plurality of laser diodes 110 having a wavelength of λ_p for modulating each frequency generated

from the frequency generators 100, and a plurality of optical-delay modules 120 for delaying each frequency optically modulated by the laser diodes 110 according to predetermined times.

In operation, a first to an N^{th} wavelength-division demultiplexers 30 demultiplex each signal inputted through a first to an N^{th} input ports respectively. Optical couplers 40 couple each output signal of the wavelength-division demultiplexers 30 with each path-monitoring information generated from the path-information-generating section 10. Optical switches 50 switch each optical signal coupled with the path-monitoring information at the optical couplers 40 according to predetermined switching information. Wavelength-division multiplexers 60 multiplex optical signals transmitted through the optical switches 50.

A path-information-detecting section 20 comprises a plurality of optical circulators 70, a plurality of optical receivers 80, a plurality of fiber Bragg gratings (reflection filters) 90, and a frequency/time-slot-detection unit 150. The optical circulators 70 detect a path-monitoring wavelength λ_1 from data coupled with path-monitoring information and outputted from the wavelength-division multiplexers 60. The optical receivers 80 convert each path-monitoring wavelength λ_1 detected by each optical circulator 70 to an electric signal. The fiber Bragg gratings 90 output data received through each optical circulator 70 to a first to an N^{th} output ports respectively. The frequency/time-slot-detection unit 150 detects the time slot and frequency from each electric-signal output from each optical receiver 80.

A path-control section comprises a switch-control unit 130, a comparator 140, and a switching-table unit 160. The switching-table unit 160 stores switching information of

each optical signal inputted through the first input port to the N^{th} input port.

The comparator 140 compares the path-monitoring information detected through the frequency/time-slot-detection unit 150 with the routing/switching information stored in the switching-table unit 160. If an erroneous path is detected, the switch-control unit 130
5 controls the optical switches 50 to correct the erroneous path.

In the embodiment, the method for monitoring the wavelength-signal paths of the optical-signal-path-monitoring/correcting apparatus uses time frames. That is, each time frame has the same number of time slots as the number of inputted wavelengths and each input-data wavelength, so the pertinent input port is detected by the position of each time
10 slot.

For example, in a case in which a second frequency f_2 is positioned at the first time slot of a time frame, the number 2 of the second frequency f_2 represents a second input port and the first time slot represents that the input data is λ_1 . That is, the position of each time slot in time frame represents input data, whereas the number of pertinent frequency
15 represents the number of input ports. As a further example, in a case in which a seventh frequency f_7 is positioned at a third time slot of the time frame, the number 7 of the seventh frequency f_7 represents the seventh input port, and the third time slot represents that the input data is λ_3 .

FIG. 3 is a detailed view of an optical-delay module 120 shown in FIG. 2. As
20 shown, each optical-delay module 120 comprises optical couplers 120-1 for distributing an optical-modulated frequency inputted from a pertinent laser diode 110, and a plurality of fiber-delay lines 120-2 for delaying and outputting in an orderly manner the distributed

frequencies according to predetermined intervals.

FIG. 4 is a detailed view of a frequency/time-slot-detection unit shown 150 in FIG. 2. As shown, the frequency/time-slot-detection unit 150 comprises a plurality of electric-signal distributors 150-1 for distributing electric signals received through the optical receivers 80 according to the input wavelength, a plurality of band-pass-filter arrays 150-2 for sensing the input port by detecting the frequency component from each signal distributed according to each wavelength by the electric-signal distributors 150-1, a plurality of time-slot detectors 150-3 for detecting the time-slot position in the time frame from each electric signal inputted through the band-pass-filter arrays 150-2, and OXC switching-information generators 150-4 for generating a switched table of the input optical-signal paths using the detected frequencies and time-slot position.

FIG. 5 is a view illustrating the time frame used in an optical-signal-path-monitoring apparatus for an OXC device.

In monitoring and correcting the optical-signal paths, the input port and transmission paths of data are detected and controlled by means of the time frames. As shown in FIG. 5, each time frame T_F has N time slots $TS1$ to TSn equal to the number of wavelengths of input data. On the i^{th} frequency f_i positioned a time slot in a time frame T_F , the number i represents the input port and the pertinent time-slot position represents the wavelength of input data. For example, in the case in which a third frequency f_3 is positioned at the first time slot $TS1$ of time frame T_F as shown at (5a) in FIG. 5, it represents that a signal of wavelength λ_1 is inputted through a third input port. Also, if an N^{th} frequency f_N is positioned at an N^{th} time slot TSn of time frame T_F as shown at (5b) in

FIG. 5, it represents that a signal of wavelength λ_n is inputted through an N^{th} input port.

FIG. 6 is a view illustrating the output examples of an optical-delay module 120 shown in FIG. 2 in order to facilitate an understanding of the present invention.

Now, the operation of the optical-signal-path-monitoring/correcting apparatus used in an OXC according to a first embodiment of the present invention will be explained with reference to FIG. 2 to FIG. 6 described above.

Referring to FIG. 2, each frequency generator 100 generates a first frequency f_1 to an N^{th} frequency f_N so as to discriminate input data. The number of generated frequencies is the same number as the number of input ports. Each generated frequency component is modulated by each laser diode 110 having a wavelength of λ_p . Each modulated optical signal is then delayed by each optical-delay module 120.

Referring to FIG. 3 which illustrates a detailed construction of an optical-delay module 120, the modulated optical signal is distributed to n number of optical signals through the optical couplers 120-1, and then delayed and outputted in order according to predetermined intervals.

Referring to FIG. 6 which shows the output of the optical-delay lines 120-2, the optical signals passing the optical-delay lines 120-2 are delayed in sequence. As shown, a first optical signal 6a has no delay, a second optical signal 6b has a delay of T_F/n , and an n^{th} optical signal 6c has a delay of $((n-1) T_F)/n$. Thereafter, the optical signals are positioned in each time slot and coupled with the wavelength inputted into an OXC device by the optical couplers 40. The T_F represents the length of a time frame.

For example, with a second frequency f_2 , the number 2 of the second frequency f_2

represents a second input port of the second frequency f_2 positioned in the first time slot represents a wavelength of λ_1 . Also, the component of the second frequency f_2 positioned in the second time slot represents a wavelength of λ_2 , and the component of the second frequency f_2 positioned in an N^{th} time slot represents a wavelength of λ_n .

5 Meanwhile, optical signals inputted to the OXC are divided according to each wavelength by the wavelength-division demultiplexers 30 and then coupled with frequency components by the optical couplers 40. Here, the frequency components have a wavelength of λ_p , which represents the path-monitoring information for the wavelength, generated from the optical-delay module 120 in the path-information-generating section 10
10 and coupled in a respective time slot. Thus, a frequency component of f_2 positioned in a j^{th} time slot of a time frame is an optical signal inputted through an i^{th} input port and then coupled with a wavelength of λ_p by the optical couplers 40. The path-monitoring wavelengths λ_p coupled with optical signals by the optical couplers 40 are switched to the respective output port by the optical switches 50 according to predetermined switching
15 information.

Thereafter, the optical signals and path-monitoring wavelengths λ_p , which are switched by the optical switches 50, are multiplexed through the wavelength-division multiplexers 60, and then are inputted to the optical circulators 70 and the fiber Bragg gratings 90 in order to detect the path-monitoring wavelengths. The optical circulators 70
20 detect the path-monitoring wavelength λ_p from the inputted optical signals, but the optical signals are outputted through the fiber Bragg gratings 90.

The optical receivers 80 convert the λ_p detected by optical circulators 70 into

corresponding electric signals. The path-monitoring signals converted to the electric signals are inputted to the frequency/time-slot-detection unit 150, and then the frequency/time-slot-detection unit 150 checks whether or not switching operations of data are performed correctly by checking the input port, output port, time-slot position, and so forth.

5 Referring to FIG. 4, the electric signal inputted to the frequency/time-slot-detection unit 150 is distributed to N number of electric signals by each of the electric-signal distributors 150-1, and then inputted to the band-pass-filter arrays 150-2 for frequency detection. Using the frequency information detected by the band-pass-filter arrays 150-2, the input-port information of each pertinent optical signal can be obtained. The frequency
10 components detected by the band-pass-filter arrays 150-2 are inputted to the time-slot detectors 150-3. Then, the time-slot detectors 150-3 detect the position information of a time slot from each of the inputted frequency components.

FIG. 7 is a view illustrating an example of a time frame inputted into an frequency/time-slot-detection unit 150 according to the present invention. In particular,
15 FIG. 7 shows a case in which signals of the time frame are detected at the first output port and further shows the component of a third frequency f_3 positioned in the first time slot, the component of a first frequency f_1 positioned in the second time slot, and the component of a fifth frequency f_5 positioned in an N^{th} time slot.

The time frame passes the band-pass-filter arrays 150-2 and the time-slot detectors
20 150-3 to detect each frequency component and time-slot-position information. Then, the OXC switching-information generators 150-4 generate a switched table indicating that a signal of frequency λ_1 is from a third input port, a signal of frequency λ_2 is from a first

input port, and a signal of frequency λ_n is from a fifth input port are switched to a first output port.

The switched table generated by the OXC switching-information generators 150-4 as described above is compared, in the comparator 140, with a predetermined switching
5 table stored in the switching-table unit 160.

If the generated switched information is different from the predetermined switching information, it indicates that an erroneous switching has occurred in the OXC. Then, the comparator 140 transmits a switching-correction signal to the optical switches 50 via the switch-control unit 130, which controls the optical switches 50 so as to correct the
10 switching state of wavelength signals. Accordingly, it is possible to detect switching paths of optical signals inputted in the OXC and also to correct the erroneously switched paths.

FIG. 8 is a block diagram illustrating an optical-signal path-monitoring and correcting apparatus applicable in an OXC according to a second embodiment of the present invention.

15 Referring to FIG. 8, it is noted that the construction and operation of the second embodiment are essentially same as that described above with respect to FIG. 2, except that the second embodiment utilizes input-data-pattern generators 300 for discriminating input data, instead of the frequency generators 100 utilized in the first embodiment of FIG. 2. Also, the second embodiment utilizes an input-data-pattern/time-slot-detection unit 350 for
20 detecting the switching information of optical signals, instead of the frequency/time-slot-detection unit 150 utilized in the first embodiment of FIG. 2. Hence, the discussion of similar components described in the preceding paragraphs is omitted to avoid redundancy,

as they are described with respect to FIG. 2.

The input-data-pattern generators 300, which are devices for discriminating input ports by using predetermined bits, may discriminate a first input port, a second input port, a third input port and a fourth input port by using data patterns of '00', '01', '10', and '11' respectively. The data pattern may be provided with a variety of methods besides the one described above. Then, each data pattern generated in the input-data-pattern generators 300 is detected at the input-data-pattern/time-slot-detection unit 350.

FIG. 9 is a view illustrating a detailed construction of the input-data-pattern/time-slot-detection unit 350 shown in FIG. 8.

Input-pattern detectors 310-1 obtain input-port information from inputted electric signals by detecting each data pattern in time frames. Electric signals, in which data patterns are detected, are inputted to time-slot detectors 310-2, then the time-slot detectors 310-2 obtain the time-slot-position information of path-monitoring signals. OXC switching-information generators 310-3 generate an input/output table for the wavelength signals switched through the OXC based on the detected data-pattern information and time-slot information. The input/output table generated by the OXC switching-information generators 310-3 are compared, in the comparator 140, with a predetermined switching table stored in the switching-table unit 160.

As a result of the comparison, if there is an erroneous path, the comparator 140 transmits a switching-correction signal to the switch-control unit 130, and then the switch-control unit 130 controls the optical switches 50, so that the switching state of the optical switches 50 is corrected.

FIG. 10 is a block diagram illustrating an optical-signal-path-monitoring and correcting apparatus for the OXC according to a third embodiment of the present invention.

It is noted that the construction and operation of the third embodiment are essentially the same as that described above with respect to FIG. 2, except that the third
5 embodiment utilizes CDM (Code Division Multiple) code generators 400 for discriminating input data. Also, the input-monitoring information generated from the CDM code generators 400 is detected in a CDM-code/time-slot-detection unit 450. Thus, a discussion of similar components described in the preceding paragraphs is omitted to avoid redundancy, as they are described with respect to FIG. 2.

10 FIG. 11 is a view illustrating a detailed construction of a CDM-code/time-slot-detection unit 450 shown in FIG. 10.

Information of inputted CDM code data is detected in the CDM code detectors 450-1 and time-slot detectors 450-2. OXC switching-information generators 450-3 obtain each input port of wavelength signals switched through the OXC with information of each
15 wavelength based on the detected CDM code information and time-slot -position information.

The comparator 140 compares a CDM-code-input-information table generated from the OXC switching-information generators 450-3 with a predetermined switching table stored in the switching-table unit 160. As a result of the comparison, if there is an
20 erroneous path, the comparator 140 transmits a switching-correction signal to the switch-control unit 130, and then the switch-control unit 130 controls the optical switches 50, so that the switching state of the optical switches 50 is corrected.

While the invention has been shown and described with reference to certain preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims. Accordingly, the scope of the
5 invention is not to be limited by the above embodiments but by the claims and the equivalents thereof.